

CLAIMS

1. A liquid crystal display device comprising a pair of polarization plates each including a polarizer and a pair of protective layers laminated over the polarizer to protect the latter, the transmission axes of the polarizers being orthogonal to each other, and a liquid crystal plate disposed between the polarization plates and including a liquid crystal layer having the molecules thereof aligned parallel with the absorption axis of one of the polarization plates, wherein:

each of the protective layers in the pair of polarization plate is a uniaxial retardation film laminated over at least the liquid crystal layer, having the optical axis thereof extended in the direction of its thickness and which is generally isotropic in a plane perpendicular to the thickness direction to perform as a negative retardation film whose thickness-directional refractive index is smaller than an in-plane-directional one; and

there is disposed between the liquid crystal plane and any one of the polarization plates a biaxial retardation film that compensates the dependence upon the viewing angle of the protective layer upon which light forming an angle with the viewing-angular direction is incident.

2. The device according to claim 1, wherein:

the biaxial retardation film is directed to vary in refractive index in the plane perpendicular to the direction of its thickness and show a maximum refractive index

in that plane; and

with a product of the difference between the maximum refractive index of the retardation film and the refractive index of the retardation film in a direction perpendicular, in the plane, to the direction to show the maximum refractive index and the thickness of the retardation film being taken as an in-plane light path length difference of the retardation film, and with a product of the difference between the thickness-directional refractive index and in-plane-directional one, of the protective layer and the thickness of the protective layer being taken as a light path length difference of the protective layer,

the in-plane light path length difference of the retardation film is set with a predetermined wavelength in a visible domain on the basis of the light path length difference of the protective layer and predetermined wavelength to compensate the dependence upon the viewing angle for incident light forming an angle with the viewing-angular direction.

3. The device according to claim 1, wherein the absorption axis of one of the polarization plates is directed in a direction for an abnormal light refractive index of the liquid crystal layer.

4. The device according to claim 1, wherein:

the liquid crystal layer is configured to turn on in the in-plane switching (IPS) mode; and

the protective layers are formed from triacetyl cellulose (TAC).

5. The device according to claim 1, wherein:

each of the protective layers in the pair of polarization plate is a uniaxial retardation film whose thickness is d_{TAC0} , having the optical axis thereof extended in the direction of its thickness and which is generally isotropic in a plane perpendicular to the thickness direction to perform as a negative retardation film whose thickness-directional refractive index n_{zt} is smaller than an in-plane-directional one n_{xy} ;

the biaxial retardation film has a thickness of d_{RF} , shows a refractive index of $n_x > n_z > n_y$ and generally meets a relation $n_z = (n_x + n_y)/2$ (where n_z is a refractive index in the direction of thickness, n_x is maximum refractive index in a plane perpendicular to the thickness direction and n_y is a refractive index in a direction perpendicular to a direction for the maximum refractive index n_x and thickness direction for a refractive index n_z); and

on the assumption that with a predetermined wavelength λ in the visible light domain, the in-plane light path length difference $\Delta n_{d_{RF}}$ of the retardation film is $(n_x - n_y) \cdot d_{RF}$ and absolute value $\Delta n_{d_{TAC0}}$ of the negative light path length difference of the protective layers is $(n_{xy} - n_{zt}) \cdot d_{TAC0}$, the direction of the retardation film for the maximum refractive index n_x coincides with the direction in which the liquid crystal molecules are aligned for the abnormal light refractive index and the plane-directional light path length difference $\Delta n_{d_{RF}}$ of the retardation film is given nearly by the following equation:

$$\Delta nd_{RF} = \frac{\lambda}{2\pi} \left[\pi - 2 \tan^{-1} \left(\frac{4\pi}{\lambda} \Delta nd_{TAC0} \right) \right]$$

6. The device according to claim 5, wherein on the assumption that the thickness of the liquid crystal layer in the liquid crystal plate is d_{LC} , abnormal light refractive index of liquid crystal molecules of the liquid crystal layer is n_e , normal light refractive index is n_o , light path length difference Δnd_{LC} of the liquid crystal layer in the liquid crystal plate is $(n_e - n_o) \cdot d_{LC}$, the light path length difference Δnd_{LC} of the liquid crystal layer in the liquid crystal plate is generally $\lambda/2$ with a predetermined wavelength λ in the visible light domain.

7. The device according to claim 5, wherein the pretilt angle of the liquid crystal molecules at the interface of the liquid crystal layer of the liquid crystal plate with the substrate is within a range of 0 to 2 deg.

8. The device according to claim 2, comprising the pair of polarization plates each including a polarizer and a pair of protective layers laminated over the polarizer to protect the latter, the transmission axes of the polarizers being orthogonal to each other, and a liquid crystal plate disposed between the polarization plates and including a liquid crystal layer having the molecules thereof aligned parallel with the absorption axis of one of the polarization plates, wherein:

the biaxial retardation film has a thickness of d_{RF} , shows a refractive index of n_x

> $n_z > n_y$ and generally meets a relation $n_z = (n_x + n_y)/2$ (where n_z is a refractive index in the direction of thickness, n_x is maximum refractive index in a plane perpendicular to the thickness direction and n_y is a refractive index in a direction perpendicular to a direction for the maximum refractive index n_x and thickness direction for a refractive index n_z); and

on the assumption that with a predetermined wavelength λ in the visible light domain, the in-plane light path length difference Δn_{RF} of the retardation film is $(n_x - n_y) \cdot d_{RF}$ and absolute value Δn_{TAC0} of the negative light path length difference of the protective layers is $(n_{xy} - n_{zt}) \cdot d_{TAC0}$, the direction of the retardation film for the maximum refractive index n_x coincides with the direction in which the liquid crystal molecules are aligned for the abnormal light refractive index and the plane-directional light path length difference Δn_{RF} of the retardation film is given nearly by the following equation:

$$\Delta n_{RF} = \frac{\lambda}{2\pi} \left[\pi + 2 \tan^{-1} \left(\frac{4\pi}{\lambda} \Delta n_{TAC0} \right) \right]$$

9. The device according to claim 8, wherein on the assumption that the thickness of the liquid crystal layer in the liquid crystal plate is d_{LC} , abnormal light refractive index of liquid crystal molecules of the liquid crystal layer is n_e , normal light refractive index is n_o , light path length difference Δn_{LC} of the liquid crystal layer in the liquid

crystal plate is $(n_e - n_o) \cdot d_{LC}$, the light path length difference Δn_{LC} of the liquid crystal layer in the liquid crystal plate is generally $\lambda/2$ with a predetermined wavelength λ in the visible light domain.

10. The device according to claim 8, wherein the pretilt angle of the liquid crystal molecules at the interface of the liquid crystal layer of the liquid crystal plate with the substrate is within a range of 0 to 2 deg.

11. A liquid crystal display device including a pair of polarization plates each formed from a polarizer whose transmission axis is orthogonal to that of a polarizer in the other polarization plate and a liquid crystal plate disposed between the polarization plates and including a liquid crystal layer having the molecules thereof aligned parallel with the absorption axis of one of the polarization plates, wherein:

each of the pair of polarization plates has a protective layer laminated over the surface thereof at the side of the crystal layer, the protective layers in pair being equal in thickness to each other and performing as a uniaxial retardation film having a negative phase difference;

a first retardation film and second retardation film are disposed between the liquid crystal plate and polarization plates, respectively;

the first retardation film is set to have a light path length difference for a polarization which would be before incident light passes through the liquid crystal layer;

the second retardation film is a biaxial retardation film whose refractive index in

the direction of its thickness is different from that in a plane perpendicular to the thickness direction and which includes a direction in which there is a maximum refractive index n_x ;

the in-plane light path length difference of the retardation film, defined as a product of the difference and the thickness of the retardation film is set to about $\lambda/2$; and

the first and second retardation films optically compensate the change in polarization of the light having passed through the pair of protective layers.

12. The device according to claim 11, wherein the second retardation film meets a relation $n_z = (n_x + n_y)/2$.

13. The device according to claim 11, wherein the first retardation film is a biaxial one or a positive uniaxial one.

14. The device according to claim 11, wherein the pretilt angle of the liquid crystal molecules at the interface of the liquid crystal layer of the liquid crystal plate with the substrate is within a range of 0 to 2 deg.

15. The device according to claim 11, wherein:

the first retardation film is a biaxial one having a thickness d_{RF1} and shows a refractive index of $n_x > n_z > n_y$ (n_z is the thickness-directional refractive index, n_x is the maximum refractive index in a plane perpendicular to the thickness direction, and n_y is the refractive index in a direction perpendicular to the direction for the maximum refractive index n_x and thickness direction) in this order;

each of the protective layers is a uniaxial retardation film whose thickness is d_{TAC0} , having the optical axis thereof extended in the direction of its thickness and which is generally isotropic in a plane perpendicular to the thickness direction to perform as a negative retardation film whose thickness-directional refractive index n_z is smaller than an in-plane-directional one n_{xy} ;

on the assumption that with a predetermined wavelength in the visible light domain, the in-plane light path length difference Δn_{RF1} of the retardation film is $(n_x - n_y) \cdot d_{RF1}$ and absolute value Δn_{TAC0} of the negative light path length difference of the protective layers is $(n_{xy} - n_z) \cdot d_{TAC0}$, the direction of the retardation film for the maximum refractive index n_x coincides with the direction in which the liquid crystal molecules are aligned for the abnormal light refractive index and the plane-directional light path length difference Δn_{RF1} of the retardation film is given nearly by the following equation:

$$\Delta n_{RF1} = \frac{\lambda}{2\pi} \left[2 \tan^{-1} \left(\frac{4\pi}{\lambda} \Delta n_{TAC0} \right) \right]$$

16. The device according to claim 11, wherein on the assumption that the thickness of the liquid crystal layer in the liquid crystal plate is d_{LC} , abnormal light refractive index of liquid crystal molecules of the liquid crystal layer is n_e , normal light refractive index is n_o , light path length difference Δn_{LC} of the liquid crystal layer in the liquid crystal plate is $(n_e - n_o) \cdot d_{LC}$, the light path length difference Δn_{LC} of the

liquid crystal layer in the liquid crystal plate is generally $\lambda/2$ with a predetermined wavelength λ in the visible light domain.

17. The device according to claim 11, wherein:

the first retardation film is a biaxial one having a thickness d_{RF1} and shows a refractive index of $n_x > n_z > n_y$ (n_z is the thickness-directional refractive index, n_x is the maximum refractive index in a plane perpendicular to the thickness direction, and n_y is the refractive index in a direction perpendicular to the direction for the maximum refractive index n_x and thickness direction) in this order;

each of the protective layers is a uniaxial retardation film whose thickness is d_{TAC0} , having the optical axis thereof extended in the direction of its thickness and which is generally isotropic in a plane perpendicular to the thickness direction to perform as a negative retardation film whose thickness-directional refractive index n_{zt} is smaller than an in-plane-directional one n_{xy} ;

on the assumption that with a predetermined wavelength λ , the in-plane light path length difference $\Delta n d_{RF1}$ of the retardation film is $(n_x - n_y) \cdot d_{RF1}$ and absolute value $\Delta n d_{TAC0}$ of the negative light path length difference of the protective layers is $(n_{xy} - n_{zt}) \cdot d_{TAC0}$, the direction of the retardation film for the maximum refractive index n_x is orthogonal to the direction in which the liquid crystal molecules are aligned for the abnormal light refractive index and the plane-directional light path length difference $\Delta n d_{RF1}$ of the retardation film is given nearly by the following equation:

$$\Delta nd_{RF1} = \frac{\lambda}{2\pi} \left[2\pi - 2 \tan^{-1} \left(\frac{4\pi}{\lambda} \Delta nd_{TAC0} \right) \right]$$

18. The device according to claim 11, wherein:

the first retardation film is a biaxial one having a thickness d_{RF1} and shows a refractive index of $n_x > n_z = n_y$ (n_z is the thickness-directional refractive index, n_x is the maximum refractive index in a plane perpendicular to the thickness direction, and n_y is the refractive index in a direction perpendicular to the direction for the maximum refractive index n_x and thickness direction) in this order; and

on the assumption that with a predetermined wavelength λ of the visible light domain, the in-plane light path length difference $(n_x - n_y) \cdot d_{RF1}$ of the retardation film is Δnd_{RF1} , thickness of the liquid crystal layer in the liquid crystal plate is d_{LC} , abnormal light refractive index of the liquid crystal molecules of the liquid crystal layer is n_e , normal light refractive index of the liquid crystal molecules of the liquid crystal layer is n_o and light path difference $(n_e - n_o) \cdot d_{LC}$ is Δnd_{LC} , the direction for the maximum refractive index n_x coincides with the direction for the abnormal light refractive index of the liquid crystal molecules aligned in the liquid crystal layer and the sum of the liquid crystal length difference Δnd_{RF1} and light path length difference Δnd_{LC} of the liquid crystal layer is generally λ .